



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification<sup>6</sup> :  
C22F 1/04

A1

(11) International Publication Number: WO 96/10655

(43) International Publication Date: 11 April 1996 (11.04.96)

(21) International Application Number: PCT/US94/11219

(22) International Filing Date: 3 October 1994 (03.10.94)

## (60) Parent Application or Grant

(63) Related by Continuation

US

004,104 (CON)

Filed on

10 January 1993 (10.01.93)

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(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SI, SK, TJ, TT, UA, US, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, MW, SD, SZ).

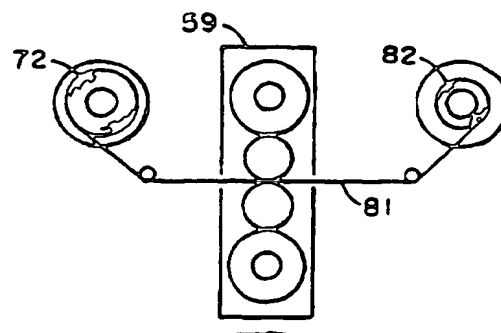
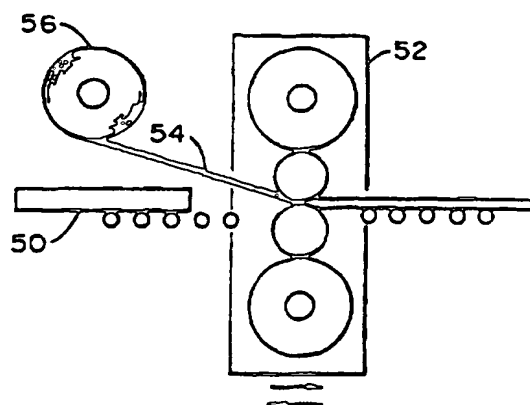
## Published

With international search report.

(54) Title: METHOD OF PRODUCING ALUMINUM CAN SHEET HAVING HIGH STRENGTH AND LOW EARING CHARACTERISTICS

## (57) Abstract

A method of producing aluminum can sheet having high strength and low earing characteristics comprises providing an aluminum alloy ingot (50) and then hot rolling the ingot (50) in a single-stand hot reversing mill (52) to produce a first intermediate gauge sheet (54). The first intermediate gauge sheet (54) is then cold rolled (59) to produce a second intermediate gauge sheet (59a). This second intermediate gauge sheet (59a) is passed through a heat source (62) as a single web so that the second intermediate gauge sheet (59a) is continuously annealed. After heating, the second intermediate gauge sheet (59a) is quenched and coiled again. Finally, the coiled second intermediate gauge sheet (70) is cold rolled (59) again to produce the final gauge aluminum can sheet (81) having high strength and low earing characteristics. These process steps are depicted in Fig. 2A, Fig. 2C, Fig. 2D, and Fig. 2E.



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METHOD OF PRODUCING ALUMINUM CAN SHEET HAVING  
HIGH STRENGTH AND LOW EARING CHARACTERISTICS

This invention relates to a method of producing aluminum can sheet having high strength and low earing characteristics and more specifically to hot rolling aluminum can sheet ingot in a single-stand reversing hot finish mill and subsequently cold rolling using an intermediate gauge continuous anneal before cold rolling the sheet again to its final thickness.

In the formation of aluminum can sheet into cup-shaped articles, a characteristic known as "earing" manifests itself as a scalloped appearance around the top edge of the formed cup. The scallops, or ears as they are more commonly known, are formed during the deep drawing step in the fabrication of the cup and represent an undesirable feature of the article. In can body stock the cup is subsequently ironed in multiple rings which accentuates the scalloped ears. High earing, therefore, can create transport problems with the cup as well as insufficient trim after ironing, clipped ears, and trimmer jams all of which are unacceptable in can manufacturing. Thus, it is desired to minimize earing in aluminum can sheet in order to avoid these costs and to increase

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the quality of the cup. See United States Patent No. 3,318,738, the disclosure of which is incorporated herein by reference.

5 It is also desirable to provide high strength in aluminum can sheet. Strength is measured by evaluating the yield strength after  
10 subjecting tensile specimens to an air temperature of 204°C. (400°F.) for 20 minutes. This process simulates the lacquer curing process of the formed and coated can and is  
15 therefore used as an indication of the finished can strength. As is well known, the yield strength measurement is obtained from a tension test in which a specimen is subjected to  
20 increasing axial load until it fractures. The yield strength is defined as the stress which will produce a small amount of permanent deformation.

Heretofore, in order to obtain  
20 acceptable low earing and high strength characteristics, a multiple-stand hot continuous mill was usually employed. As can be seen in Figure 1, this involves providing one or more  
25 hot reversing or breakdown mills 10 which roll the 12 inch - 24 inch thick incoming ingot 12 to an intermediate gauge slab 14. The intermediate gauge slab 14 is then introduced into a series  
30 of 3-6 (three are shown in Figure 1) hot rolling stands 16, collectively referred to as a "hot continuous mill", to reduce the intermediate gauge slab 14 to an approximately .1 inch thick final hot rolled sheet 17. The final thickness  
35 hot rolled sheet 17 is then coiled on a coil 18. The coil 18 can then optionally be batch annealed at 315°C. to 426°C. (600-800°F.) for 1-6 hours in a furnace 20. After this the sheet 17 is unwound from coil 18 and cold rolled in a

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cold rolling mill 22 to produce the final thickness sheet 24 (0.0100-0.0130 inches thick) which is subsequently wound onto coil 26.

5       The hot continuous mill, while effective in producing low earing and high strength characteristics in the aluminum can sheet, represents a major capital expenditure. In addition, this process requires extensive coordination of the individual roll stands  
10       within the continuous mill for successful fabrication. Thus, it would be desirable to eliminate the hot continuous mill in order to substantially reduce the capital expense for producing aluminum can sheet, but only if  
15       aluminum can sheet can be produced which has low earing and high strength characteristics.

          However, until the invention described herein, attempts to produce aluminum can sheet by eliminating the hot continuous mill have not  
20       been successful in producing aluminum can sheet having commercially acceptable low earing and high strength characteristics. These known processes in which the hot continuous mill has been eliminated produce aluminum can sheet  
25       having either unacceptably high earing or unacceptably low post-bake yield strength or both.

          Thus, there is a need for an improved method of producing aluminum can sheet in a  
30       single-stand hot reversing mill that has low earing and high strength characteristics.

          The method of the invention has met the above-described need. The method of producing aluminum can sheet having high  
35       strength and low earing characteristics comprises providing an aluminum alloy ingot and then hot rolling the ingot in a single-stand hot

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reversing mill to produce a first intermediate gauge sheet. The first intermediate gauge sheet is then cold rolled to produce a second intermediate gauge sheet. This second intermediate gauge sheet is passed through heating means so that the second intermediate gauge sheet is continuously annealed. After heating, the second intermediate gauge sheet is quenched and coiled again. Finally, the coiled second intermediate gauge sheet is cold rolled again to produce the final gauge aluminum can sheet having high strength and low earing characteristics.

A full understanding of the invention can be gained from the following description of the preferred embodiment when read in conjunction with the accompanying drawings in which:

Figure 1 A-D is a schematic drawing of the prior art method of using a hot continuous mill.

Figure 2 A-E is a schematic drawing showing an embodiment of the invention wherein a single-stand hot mill is utilized.

Referring now particularly to Figure 2 A-E, a schematic drawing illustrating an embodiment of the invention is shown. An ingot 50 is shown which is ready to be hot rolled. The ingot 50 is an aluminum alloy which is suitable for use as can sheet such as 3004 or 3104 alloy containing about 0.10 to 0.30% Si, about 0.20 to 0.50% Fe, about 0.10 to 0.25% Cu, about 0.8 to 1.5% Mn and about 0.8 to 1.5% Mg, the balance being aluminum and incidental elements and impurities.

The ingot 50 is pretreated in a known way by machining or scalping the surfaces

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thereof to remove a portion of the metal thickness from each surface. This will remove surface defects from the ingot 50 which are created during the casting process. Following  
5 scalping, the ingot 50 is heated in a furnace and held at this raised temperature for a period of time. The ingot 50 is then cooled, while in the furnace, at a controlled rate for a certain period of time and then is cooled to a hot  
10 rolling temperature.

The pretreated ingot 50 is now ready to be hot rolled in the single-stand reversible hot rolling mill 52. The pretreated ingot 50 has a thickness of about 26.5 to 60.0 cm (10.4  
15 to 23.6 inches), with 51 cm (20 inches) being preferred. The ingot 50 is successively hot rolled on the single-stand hot rolling mill 52 to a thickness of about 0.18 to 0.64 cm (0.070 to 0.250 inches), with 0.30 cm (0.120 inches)  
20 being preferred to produce a first intermediate gauge sheet 54. The first intermediate gauge sheet 54 exits the single stand hot rolling mill 52 at a temperature of about 249 to 405°C. (480 to 760°F.), with 350°C. (662°F.) being  
25 preferred. The first intermediate gauge sheet 54 is wound onto a coil 56. After this, the exit temperature of the first intermediate gauge sheet 54 is determined. If the exit temperature of the first intermediate gauge sheet 54 is  
30 lower than about 343°C. (650°F.), the coil 56 is annealed in a box type furnace 58 at about 329° to 399°C. (625 to 750°F.) with 360°C. (680°F.) being preferred and held at that temperature for about 1-12 hours, with about 2 hours being  
35 preferred and then allowed to cool to room temperature. If the exit temperature is higher than about 343°C. (650°F.), the coil 56 will

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"self anneal" due to the latent heat of hot rolling and thus the annealing step set forth above is not necessary.

After annealing, first intermediate gauge sheet 54 is then cold rolled in cold mill 59 to produce a cold rolled second intermediate gauge sheet 59a having a thickness of about 0.05 to 0.127 cm (0.020 to 0.050 inches). This cold rolled second intermediate gauge sheet 59a is then wound on a coil 59b. The coil 59b containing the cold rolled second intermediate gauge sheet 59a is then moved to a continuous anneal line 60.

At the continuous anneal line 60, the cold rolled second intermediate gauge sheet 59a is uncoiled from coil 59b and passes through an elongated heating means 62. The heating means 62 has an entrance end 62a into which the sheet 59a is introduced and an exit end 62b out of which the sheet 59a emerges after being continuously annealed. As the sheet 59a is passed continuously through the heating means 62 as a single web, the heat-up rate of the sheet 59a is greatly increased over that of batch annealing.

The heating means 62 is maintained at a temperature of about 427 to 566°C. (800 to 1050°F.), with 524°C. (975°F.) being preferred. The heat treatment can take place in as little as 45 seconds, or less, for example 30 to 60 seconds, with times of about 2 to 180 seconds at the heat treating temperature being suitable. The heating means 62 can be an electrical induction furnace or forced air convection furnace. The exit temperature of the sheet 59a is about 524°C. (975°F.).

After exiting the heating means 62 at



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exit end 62b, the cold rolled second intermediate gauge sheet 59a is sprayed by a coolant, such as water 66, from water jets 68 supplied by a water source (not shown). It will be appreciated that the coolant can also be air from air jets supplied from a pressurized air source. The coolant acts to rapidly quench the cold rolled second intermediate gauge sheet 59a. This will enhance the strain hardening rate (strengthening) of the cold rolled second intermediate gauge sheet 59a during the subsequent cold rolling by minimizing the precipitation of solute (Cu, Mg, Mn atoms) in the sheet which would otherwise have occurred during slow cooling. The quenched cold rolled second intermediate sheet 70 is then wound on a coil 72. It is preferred that the quench rate is at least 10°C./sec (18°F./sec) from heat treatment temperature to a temperature of 10 to 121°C. (50 to 250°F.) with 32°C. (90°F.) being preferred for the quenched cold rolled second intermediate sheet 70 after quenching.

The coil 72 of quenched cold rolled second intermediate sheet 70 is then cold rolled through cold mill 59 to the final thickness of about 0.0254 to 0.033 cm (0.010 to 0.013 inches), and the final gauge sheet 81 is wound onto a coil 82.

#### EXAMPLE

As an example of the application of the present invention, an aluminum melt was adjusted to have the concentration of elements listed in Table 1.

Table 1

<u>Si</u>	<u>Fe</u>	<u>Cu</u>	<u>Mn</u>	<u>Mg</u>
0.17	0.39	0.19	1.11	1.5

The resulting alloy composition was cast by the

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direct chill method into 4 ingots of dimensions 50 cm x 147 cm x 518 cm (19.7 in. x 58 in. x 204 in.)

5           The broad surfaces of all four ingots were scalped to remove about 1.5 cm (0.6 inch) casting roughness from each surface. Following machining the ingots were heated in a furnace to a temperature of about 593°C. (1100°F.), holding at this temperature for 4 hours, then cooling  
10       the ingots at a controlled rate of 6°C./hour (11°F./hour) to a temperature of about 510°C. (950°F.), then removed from the furnace and allowed to air cool. The broad surfaces were again machined to remove about .71 cm (0.28  
15       inch) of thickness per side.

          Prior to hot rolling, the ingots were placed in one furnace and reheated to a temperature of 510°C. (950°F.) and allowed to equilibrate at this temperature for about a two  
20       hour period. The ingots were then successively hot rolled on a single-stand reversing mill to produce a first intermediate gauge thickness sheet having a thickness of .3 cm (0.120 inch) and exited the rolling mill at temperatures from  
25       about 338°C. to 349°C. (640°F. to 660°F.). The first intermediate gauge thickness sheet was then wound onto coils. The coils were next annealed in a box-type furnace at about 360°C. (680°F.) for a minimum of four hours and allowed  
30       to cool to room temperature.

          Following annealing was a cold rolling step which reduced the metal thickness to about 0.0762 cm (0.030 inch). The cold rolled sheet was then wound onto coils. At this point two of  
35       th four coils were subject d to a standard batch anneal by placing them in a box-type furnace and heating to about 360°C. (680°F.) for

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a minimum of four hours, followed by ambient air cooling to room temperature. The other two coils were annealed on a continuous anneal line which was accomplished by unwinding the coil and passing the strip through a heating means, such as heating means 62, which was maintained at a temperature of about 524°C. (975°F.), water spray quenching the strip at the end of the box, and rewinding. All four coils were further cold rolled to about 0.0325 cm (0.0128 inch) thickness.

Testing of resulting strip demonstrated the strength and earing values listed in Table 2. Strength was measured in the post-baked condition to more closely simulate the formed can strength. The post-baked samples were exposed to a 204°C. (400°F.) air furnace for 20 minutes prior to testing. Yield strength was determined using a common tension test wherein the specimen was subjected to a continually increasing force while simultaneous observations were made of the elongation. The yield strength was defined as the load necessary to induce a 0.2% length increase of the specimen divided by the cross-sectional area of the specimen. It is measured in dimensions of Mega Pascals (MPa). The English equivalent is thousands of psi (pounds per square inch) or ksi. Earing values were determined by the common method of drawing a cup 40%. This means that the punch diameter was 40% smaller than the sheet circle diameter. The earing value is expressed as the percent difference between the lowest and highest heights of the drawn cup sidewall.

Table 2

<u>Ann al</u> <u>Type</u>	<u>Post Bake Yield Strength</u>			<u>45° Earing</u>		
	<u>No. of</u> <u>Tests</u>	<u>Average</u>	<u>Standard</u> <u>Deviation</u>	<u>No. of</u> <u>Tests</u>	<u>Average</u>	<u>Standard</u> <u>Deviation</u>
Batch	8	246.33 MPa	0.90 MPa	32	3.83%	0.057%
Continuous	8	282.21 MPa	1.73 MPa	32	2.86%	0.063%

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5 As can be seen, the continuously annealed sheet exhibited greater average post bake yield strength and lower 45° earing than the batch annealed sheet. These results meet or exceed current product requirements whereas the batch annealed material is both too low in yield strength and too high in earing to be commercially acceptable.

10 While the invention has been described in terms of preferred embodiments, the claims appended hereto are intended to encompass all embodiments which fall within the spirit of the invention.

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C L A I M S

1. A method of producing aluminum can sheet having high strength and low earing characteristics, said method comprising:
  - 5 providing an aluminum alloy ingot;  
hot rolling said ingot, said hot rolling step consisting of hot rolling in a single-stand hot reversing mill to produce a first intermediate gauge sheet;
  - 10 cold rolling said first intermediate gauge sheet to produce a second intermediate gauge sheet;
  - passing said second intermediate gauge sheet through heating means to continuously
  - 15 anneal said second intermediate gauge sheet;  
cooling said second intermediate gauge sheet; and
  - cold rolling said second intermediate gauge sheet to produce said aluminum can sheet
  - 20 having high strength and low earing characteristics.
2. The method of claim 1, wherein said aluminum alloy ingot consists essentially of about 0.10 to 0.30% Si, about
- 25 0.20 to 0.50% Fe, about 0.10 to 0.25% Cu, about 0.8 to 1.5% Mn, and about 0.8 to 1.5% Mg, the balance being aluminum and incidental elements and impurities.
3. The method of claim 1, wherein
- 30 said aluminum alloy ingot is composed of 3004 aluminum alloy.
4. The method of claim 1, wherein said ingot has a thickness of at least 26.5 cm (10.4 inches).
- 35 5. The method of claim 4, wherein said ingot has a thickness of between about 26.5 cm and 60.0 cm (10.4 to 23.6 inches).

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6. The method of claim 1, including  
after hot rolling, winding said first  
intermediate gauge sheet on a coil.
7. The method of claim 6, including if  
5 said first intermediate gauge sheet has a  
temperature of less than 343°C. (650°F.),  
heating said coil in a furnace to a temperature  
of about 329 to 399°C. (625 to 750°F.).
8. The method of claim 7, including  
10 removing said coil from said furnace  
and allowing said coil to air cool to about room  
temperature.
9. The method of claim 8, including  
winding said second intermediate gauge  
15 sheet onto a coil.
10. The method of claim 6, including  
unwinding said second intermediate  
gauge sheet from said coil; and  
passing said second intermediate gauge  
20 sheet as a single web through a heating means.
11. The method of claim 10, including  
said heating means having an entrance  
end and an exit end;  
introducing said second intermediate  
25 gauge sheet into said entrance end; and  
passing said second intermediate gauge  
sheet out of said exit end.
12. The method of claim 11, including  
maintaining the temperature in said  
30 heating means at about 427 to 566°C. (800 to  
1050°F.).
13. The method of claim 11, including  
cooling said second intermediate gauge  
sheet by quenching.
- 35 14. The method of claim 13, including  
quenching said second intermediate  
gauge sheet by spraying water on said sheet as

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it passes out of said exit end.

15. The method of claim 1, wherein said aluminum can sheet has a post bake yield strength of about 40.9 ksi.

5 16. The method of claim 1, wherein said aluminum can sheet has 45° earing of about 2.86%.

17. The aluminum can sheet produced by the method of claim 1.

10 18. A method of producing aluminum can sheet having high strength and low earing characteristics, said method comprising:

providing an aluminum alloy ingot;  
hot rolling said ingot, said hot

15 rolling step consisting of hot rolling in a single-stand hot reversing mill to produce a first intermediate gauge sheet;

20 cold rolling said first intermediate gauge sheet to produce a second intermediate gauge sheet;

continuously annealing said second intermediate gauge sheet at a temperature of at least 427°C. (800°F.);

25 cooling said second intermediate gauge sheet; and

cold rolling said second intermediate gauge sheet to produce said aluminum can sheet having high strength and low earing characteristics.

30 19. The method of claim 18, wherein said aluminum alloy ingot consists essentially of about 0.10 to 0.30% Si, about 0.20 to 0.50% Fe, about 0.10 to 0.25% Cu, about 0.8 to 1.5% Mn, and about 0.8 to 1.5% Mg, the balance being aluminum and incidental elements and impurities.

35 20. The method of claim 18, wherein



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said aluminum alloy ingot is composed of 3004 aluminum alloy.

21. The method of claim 18, wherein said ingot has a thickness of at least 26.5 cm (10.4 inches).

22. The method of claim 21, wherein said ingot has a thickness of between about 26.5 cm and 60.0 cm (10.4 to 23.6 inches).

23. The method of claim 18, wherein cooling said second intermediate gauge sheet by quenching.

24. The method of claim 23, including quenching said second intermediate gauge sheet by spraying water on said sheet as it passes out of said exit end.

25. The method of claim 18, including continuously annealing said second intermediate gauge sheet at said continuous annealing temperature for at least 2 seconds.

26. The method of claim 25, including cooling said second intermediate gauge sheet from said continuously annealing temperature to a temperature of about 10 to 121°C. (50 to 250°F.).

27. The method of claim 26, including cooling said second intermediate gauge sheet at a rate of at least about 10°C./sec (18°F./sec).

28. A method of producing aluminum can sheet having high strength and low earing characteristics, said method comprising:  
providing an aluminum alloy ingot;  
heating said ingot to a preheat temperature;

allowing said ingot to cool from said preheat temperature to room temperature;  
heating said ingot to a hot rolling

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temperature;

hot rolling said ingot, said hot  
rolling step consisting of hot rolling in a  
single-stand hot reversing mill to produce a  
first intermediate gauge sheet;

coiling said first intermediate gauge  
sheet on a first coil;

cold rolling said first intermediate  
gauge sheet to produce a second intermediate  
gauge sheet;

coiling said second intermediate gauge  
sheet on a second coil;

uncoiling said second intermediate  
gauge sheet from said second coil;

annealing said uncoiled second  
intermediate gauge sheet;

cooling said uncoiled second  
intermediate gauge sheet;

coiling said cooled second  
intermediate gauge sheet; and

cold rolling said second intermediate  
gauge sheet to produce said aluminum can sheet  
having high strength and low earing  
characteristics.

29. The aluminum can sheet produced by the  
method of claim 28.

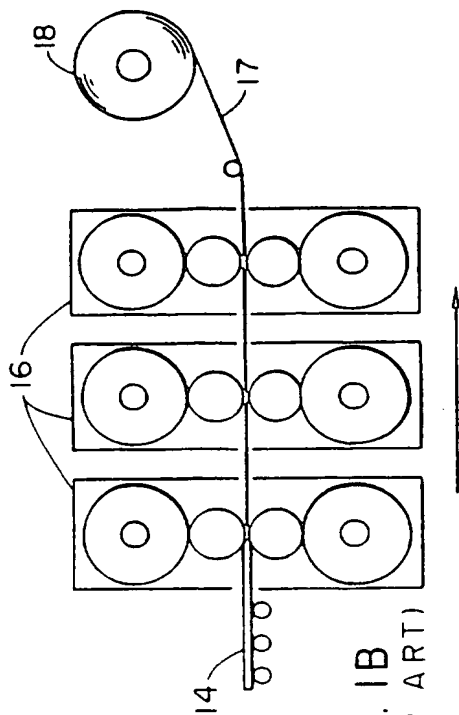


FIG. 1B  
(PRIOR ART)

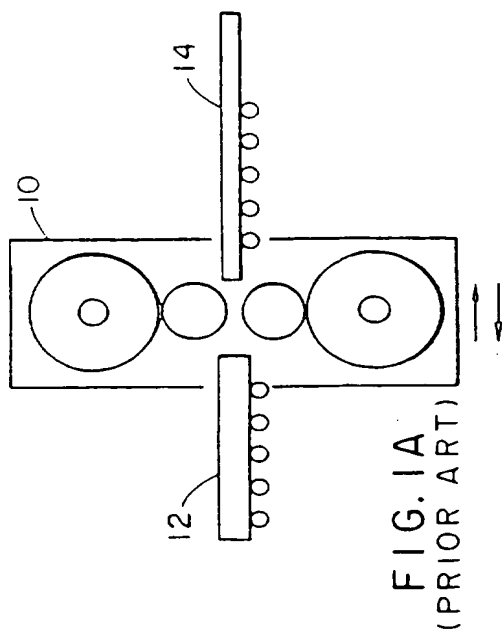


FIG. 1A  
(PRIOR ART)

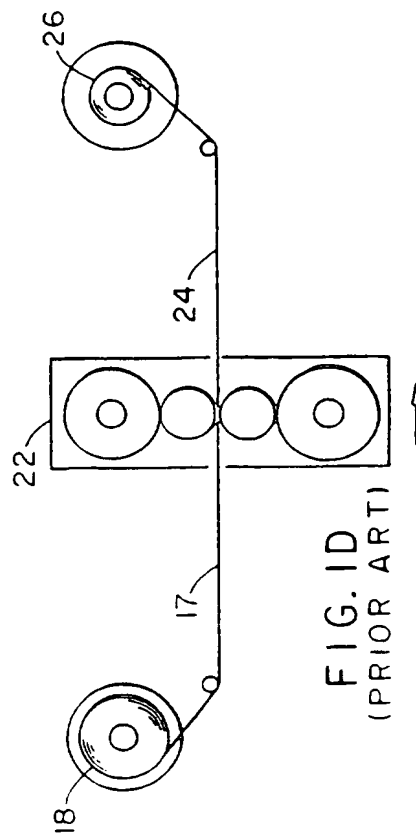


FIG. 1D  
(PRIOR ART)

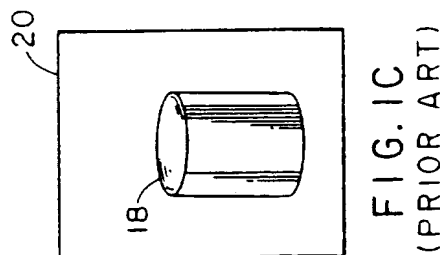
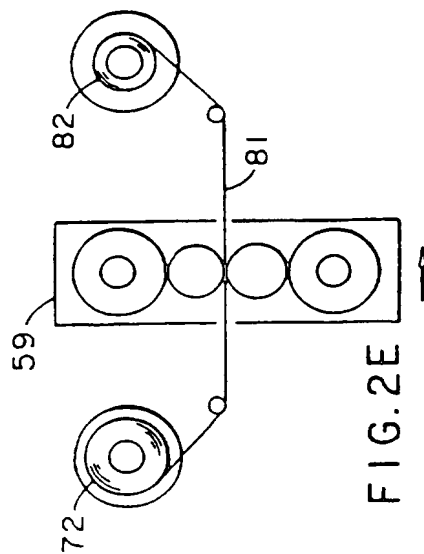
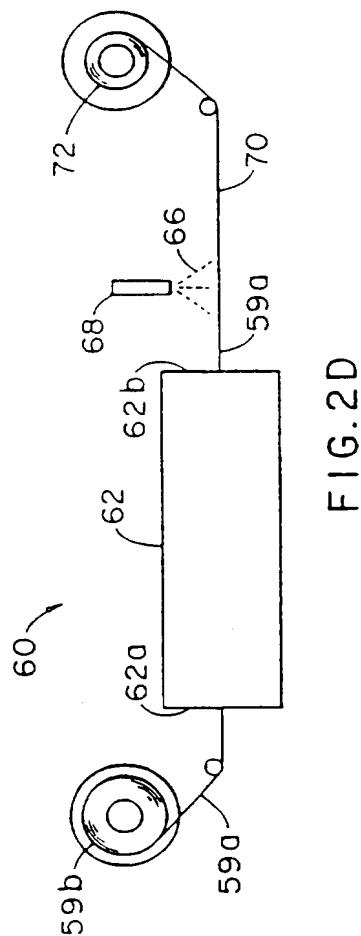
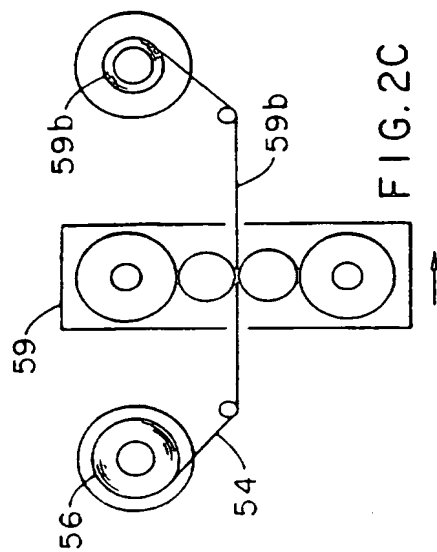
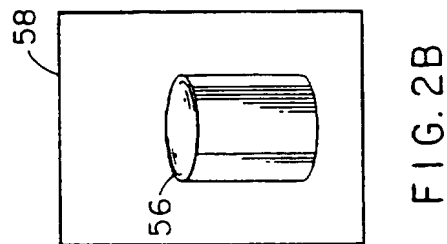
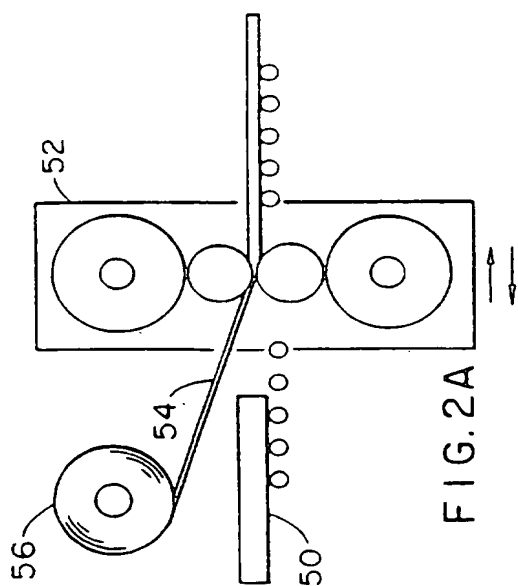


FIG. 1C  
(PRIOR ART)



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US94/11219

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : C22F 1/04

US CL : 148/692, 696, 437, 438, 439

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 148/692, 696, 437, 438, 439

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched  
None

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS Text

search terms: 63282246

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category <sup>a</sup>	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4,282,044 (ROBERTSON ET AL) 04 August 1981, col. 3, line 40 to col. 15, line 35 and col. 17, lines 6-53.	1-29
Y	JP, A, 63-282246 (KOBEL STEEL LTD) 18 November 1988, English-language Abstract (Patent Abstracts of Japan) and pages 1-7.	1-29

☐

Further documents are listed in the continuation of Box C.

☐

See patent family annex.

<sup>a</sup> Special categories of cited documents:

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Date of the actual completion of the international search

19 MAY 1995

Date of mailing of the international search report

07 JUN 1995

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